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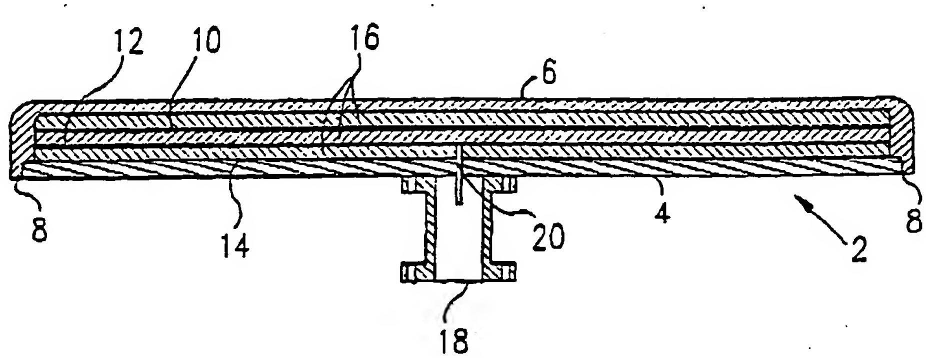
(54) **Flat plate antenna arrays**

(57) The invention comprises a flat panel antenna for microwave transmission. The antenna comprises at least one printed circuit board, and has active elements including radiating elements and transmission lines. There is at least one ground plane for the radiating elements and at least one surface serving as a ground plane for the transmission lines. The panel is arranged such that the spacing between the radiating elements and their respective groundplane is independent of the spacing between the transmission lines and their respective groundplane. A radome may additionally be provided which comprises laminations of polyolefin and an outer skin of polypropylene.

FIG. 1



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parallel to the central axis.

[0015] The number of radiating elements per row of the pattern is a function of the distance of each respective row from the central axis. That is to say each row may have a predetermined number of radiating elements and that predetermined number may increase with the proximity of each respective row to the central axis. Such an arrangement decreases the size of directional side lobes.

[0016] The antenna may further comprise a ground plate located at a predetermined distance from the printed circuit board. The predetermined distance would typically be less than a quarter of the wavelength of the signal.

[0017] In a preferred embodiment individual transmission lines split into two or more transmission lines at each of a plurality of branch points. The total impedance when taken in parallel, of the further lines following respective branch points is equal to the impedance of the individual transmission line preceding the respective branch point. The impedance of the branches is seen as a parallel impedance by the central feed point and the intention is to keep the impedance constant along the length of the transmission lines.

[0018] An embodiment of the array has the elements fed in a series/parallel fashion. This is done to reduce further losses in the transmission lines and improve efficiency.

[0019] Embodiments of the antenna may be used for transmitting or receiving one or more wavebands within the 0.5 - 40 GHz range.

[0020] The antenna may typically be sealed from the environment by a radome. The radome may comprise a rigid polypropylene skin and a foamed polyethylene body, the body being comprised of approximately 80% cross-linked polymer, the skin preferably being UV protected, and both the skin and the body being held together, preferably by soldering.

[0021] According to a second aspect of the present invention there is provided an antenna comprising at least one printed circuit board, and having active elements including radiating elements and transmission lines, mounted on said printed circuit board, and at least one ground plane for the radiating elements and at least one surface serving as a ground plane for the transmission lines. The radiating elements are arranged in rows, which are parallel to a central axis of the antenna, and the radiating elements are elongated, and arranged with their elongated directions parallel to an axis offset from the central axis of the antenna. This aspect is particularly useful where low sidelobes are less important.

[0022] According to a third aspect of the invention there is provided an antenna comprising at least one printed circuit board having two oppositely facing printed surfaces, and having active elements including radiating elements and transmission lines mounted on the oppositely facing surfaces, and at least one ground plane for the radiating elements and at least one surface serving as a ground plane for the transmission lines, wherein the transmission lines on the oppositely facing surfaces overlay each other and the radiating elements on the oppositely facing surfaces do not overlay each other.

[0023] According to a fourth aspect of the present invention there is provided an antenna comprising at least one printed circuit board, and having active elements including radiating elements and transmission lines, and at least one ground plane for the radiating elements and at least one surface serving as a ground plane for the transmission lines. The radiating elements are arranged in rows about a central axis of the antenna and the number of radiating elements per row decreases with the distance of the row from the central axis.

[0024] A preferred embodiment of the invention is an antenna comprising at least one printed circuit board, and having active elements including radiating elements and transmission lines, and at least one ground plane for the radiating elements and at least one surface serving as a ground plane for the transmission lines, arranged such that the spacing between said radiating elements and said at least one groundplane therefor is independent of the spacing between said transmission lines and said at least one surface serving as a groundplane therefor. The printed circuit board has a first surface and a second, opposing, surface and the active elements are located on both surfaces of said printed circuit board. The transmission lines of the first surface overlay the transmission lines of the second surface. The radiating elements are arranged in rows, which are parallel to a central axis of the antenna. The radiating elements are also elongated, and arranged with their elongated directions parallel to an axis offset from the central axis of the antenna. The radiating elements on the oppositely facing surfaces do not overlay each other. A predetermined number of elements is arranged in each row and that number decreases with the distance of the row from the center of the array.

[0025] According to a fifth aspect of the invention there is provided a radome for sealing an antenna. The radome comprises an outer skin and an inner body. The outer skin and the inner body may both comprise polyolefins. The inner body may be 80% cross-linked polymer. These materials are chosen for their transparency to RF radiation and, as well as the radome, may also be used for the spacers within the antenna.

[0026] The spacer may have up to 80% of cross-linked polymer, which level is determined by a specific foaming process that is used. The process is chosen to provide small cell size and extreme uniformity of the foam.

[0027] Polymers of a single group (polyolefins) have low adhesion, and the layers or laminations are preferably bonded together by a form of soldering in which no glue is used in the bonding process. The presence of glue in the material is harmful in that it increases the propensity of the material to absorb radiation. An advantage of the materials being of the same group is that the

[0038] It will be appreciated that, whether the radiating elements are positioned to be horizontal or vertical the antenna takes on the diamond shape of figure 4. It is possible to put two or more such diamond shapes together to make a composite antenna. Such a composite antenna may be advantageous in certain applications.

[0039] In an alternative embodiment the radiating elements are not at an angle of 45°. Instead, straight elements are used, and this is done where low side lobes are not required.

[0040] The array in figure 3 represents the array printed on one side of the PCB. On the opposite side of the PCB a complementary pattern is printed. The complementary pattern relates to the first pattern in that the respective transmission paths overlay one another. The radiating elements of the second pattern however, extend outwards from the terminations of the transmission lines in the opposite directions, at an angle of 180 degrees from the first radiating elements. Figure 5 shows a termination of a transmission element in which the two radiating elements 40 and 42, from the top surface and the bottom surface respectively of the PCB, are shown superimposed.

[0041] In general, the flat radiating elements 34 must be matched to the transmission lines 32. The transmission lines 32 must correspondingly be matched to the central feed point 30. This is achieved in the present invention as follows.

[0042] The flat element 34 has an impedance of typically 50 or 100 ohms. This element is followed by a transmission line 32 of the same impedance as the radiating element. The transmission line 32 is then stepped up to 100 ohms. Two such transmission lines are connected together via a T junction. The common output yields 50 ohms. This is stepped up again consecutively to 100 ohms at the next T junction. This process is repeated right up to the central input.

[0043] The impedance of the radiating elements must also be tightly controlled and this is related to the spacing between the respective PCB surfaces and the groundplane 14.

[0044] The total number of elements may range from 16 upwards, to 16,000 and beyond.

[0045] The bandwidth of the radiating element is independent of the dimensions of the transmission lines. This is because the radiating elements and the transmission lines use separate ground planes. In respect of the transmission lines the opposite face of the PCB serves as the groundplane. The separate groundplane 14 is for the radiation elements. It will be recalled from the description of figure 3 that the transmission lines of the two faces of the PCB overlay each other. Hence the opposite transmission line is able to serve as a groundplane in each case. However the radiation elements do not overlay each other and therefore the separate groundplane 14 is effective.

[0046] Flat patch array antennae of the prior art generally have bandwidths of around 1 to 4%. Embodiments of the present invention can achieve bandwidths in the region of 20%. This invention is particularly useful in large arrays where gain requirements are greater than 32dBi. A flatness of the gain peak of 0.5dB over a wide band can generally be achieved. A minimum cross-polarization of 30dB can also be achieved.

[0047] Figures 6 and 7 show upper and lower layers respectively of a series parallel feed for use in embodiments of the present invention. The series parallel feed reduces losses in the transmission lines and thus improves efficiency. The series parallel array is advantageously used when the maximum bandwidth made available by the invention is not required.

[0048] Figure 8 shows a waveguide power divider for use with the present invention. In a preferred embodiment a number of arrays can be added together by means of a waveguide power divider, and figure 8 shows, by way of example, a 16-way divider. The power divider could equally well be a four way or a sixty-four way power divider depending on the particular configuration. A problem with PCBs is that, especially at high frequencies, large numbers of radiating elements are needed. To include each one of them on the same PCB requires a large PCB with long transmission lines. Transmission lines on a PCB are less efficient than waveguides. Thus it is more efficient to have several small PCBs connected by a waveguide power divider.

[0049] Fig. 9 shows an 8 by 8 point-to-point antenna. In order to deal with the requirement that sidelobes are kept extremely low the dipole elements 50 are balanced very carefully. This may be achieved by means of the curves 52 in the transmission lines linking the dipole elements 50 to the central stems 54. Additional curves 56 serve to reduce extraneous radiation from the transmission lines and again, these contribute significantly to sidelobe performance.

[0050] The feedpoint 58 contains a special pad designed so that soldering is only required on one side of the printed circuit.

[0051] Fig. 10 shows an LMDS subscriber antenna. This antenna again shows the use of curves 52 in the transmission lines to reduce radiation.

[0052] Fig. 11 shows a base station antenna. This antenna is configured with a taper arrangement to yield a wide beam with a sharp skirt.

[0053] The antenna is sealed from the environment using the radome 6. In general foamed plastic is used in radomes and the reason is that, at the wavelengths at which the antenna operates, materials in general absorb energy from the radiation. Foamed plastic is less dense than most materials and therefore absorbs less energy, and it is a general object of the design of a radome to minimize the absorption of energy.

[0054] In the prior art the plastic used in the radome is foamed using a foaming agent. The radome has an inner body of foamed plastic, and an outer skin which need not be foamed and which is tougher than the body, to give the antenna an outer rigidity.

ther comprising a polariser.

12. An antenna according to any preceding claim wherein said radiating elements are located at a predetermined distance from said at least one groundplane therefor, which predetermined distance is chosen to maximize bandwidth.

13. An antenna according to claim 12, wherein said predetermined distance is approximately a quarter of a wavelength.

14. An antenna according to claim 10 wherein said predetermined thickness is chosen to minimize impedance in said transmission lines.

15. An antenna comprising at least one printed circuit board, and having active elements including radiating elements and transmission lines, mounted on said printed circuit board, and at least one ground plane for the radiating elements and at least one surface serving as a ground plane for the transmission lines, wherein the radiating elements are arranged in rows, which rows are parallel to a central axis of said antenna, and wherein said radiating elements are elongated, and arranged with their elongated directions parallel to an axis offset from said central axis of said antenna.

16. An antenna according to claim 6 wherein individual transmission lines split into further transmission lines at a plurality of branch points, and wherein a total electrical impedance of said further elements as seen in parallel is substantially equal to an electrical impedance of said individual transmission element preceding each respective branch point.

17. An antenna according to any of claims 1 to 14, 15 or 16, wherein said radiating elements are arranged in a plurality of rows about a central axis such that said rows are aligned parallel to said axis and said radiating elements are arranged parallel to a second axis offset from said central axis.

18. An antenna according to any of claims 1 to 14, 15 or 16, wherein said radiating elements are arranged in a plurality of rows about a central axis such that said radiating elements are arranged parallel to said central axis.

19. An antenna according to claim 17, wherein the number of radiating elements in each row decreases as a function of the distance of each respective row from said central axis.

20. An antenna comprising at least one printed circuit board having two oppositely facing printed surfaces, and having active elements including radiating elements and transmission lines mounted on said oppositely facing surfaces, and at least one ground plane for the radiating elements and at least one surface serving as a ground plane for the transmission lines, wherein the transmission lines on said oppositely facing surfaces overlay each other and said radiating elements on said oppositely facing surfaces do not overlay each other.

21. An antenna according to any preceding claim for receiving one or more wavebands within the 0.5 - 40 GHz range.

22. An antenna according to any preceding claim further comprising a radome, for sealing said antenna from the environment.

23. An antenna according to claim 22 wherein said radome comprises a foamed polyethylene body and a polypropylene skin, said body comprising approximately 80% cross-linked polymer.

24. A printed circuit board for use in the antenna of any preceding claim.

25. A printed circuit board according to claim 24 wherein at least some of said radiating elements extend from said transmission lines at angles of substantially 45°.

26. A printed circuit board according to one of claim 24 and claim 25 wherein at least some of said radiating elements extend from said transmission lines at angles of substantially 135°.

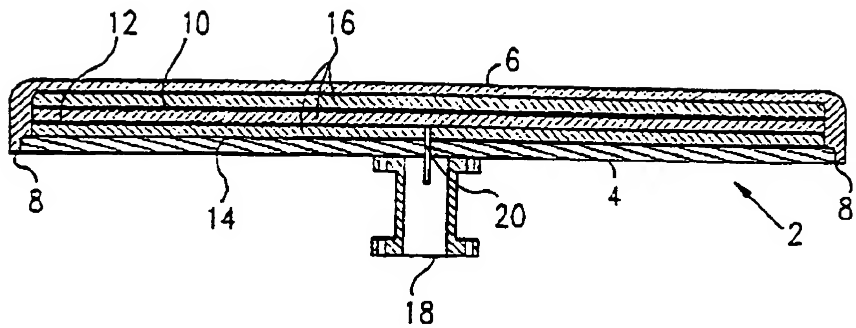
27. An antenna according to any one of claims 1 to 8 and 10 to 23 wherein radiating elements extend at predetermined angles from ends of said transmission lines.

28. An antenna comprising at least one printed circuit board, and having active elements including radiating elements and transmission lines, and at least one ground plane for the radiating elements and at least one surface serving as a ground plane for the transmission lines, wherein said radiating elements are arranged in rows about a central axis of the antenna and wherein the number of radiating elements per row decreases with the distance of said row from said central axis.

29. An antenna according to any preceding claim connected to a waveguide power divider, said waveguide power divider being connectable simultaneously to other antennae.

30. A radome, for sealing an antenna, comprising polyolefin layers bound together.

FIG. 1



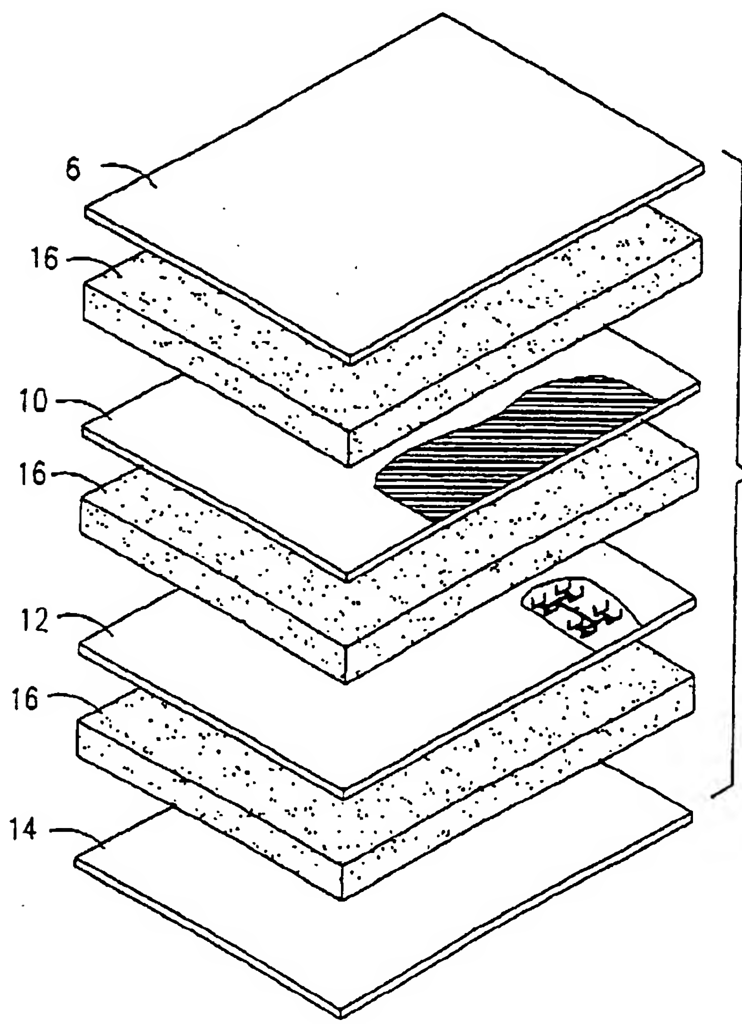


FIG. 2

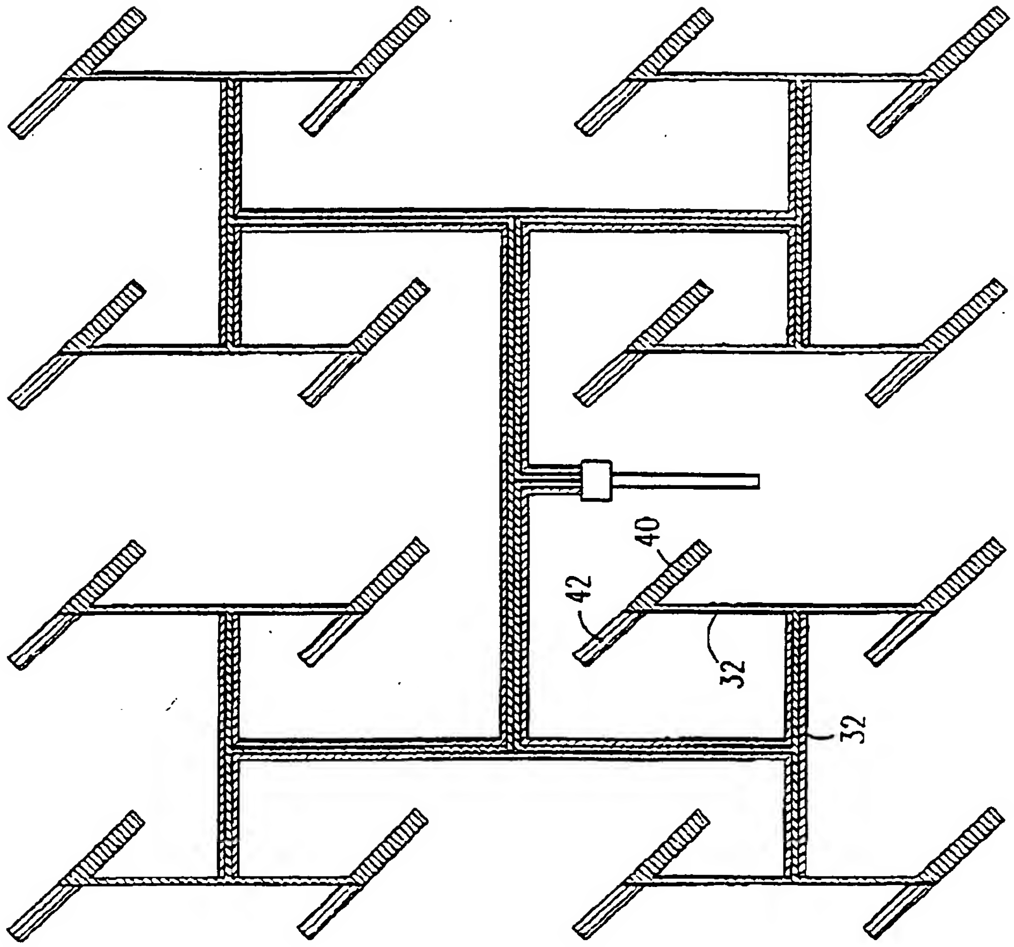


FIG. 5

FIG. 8

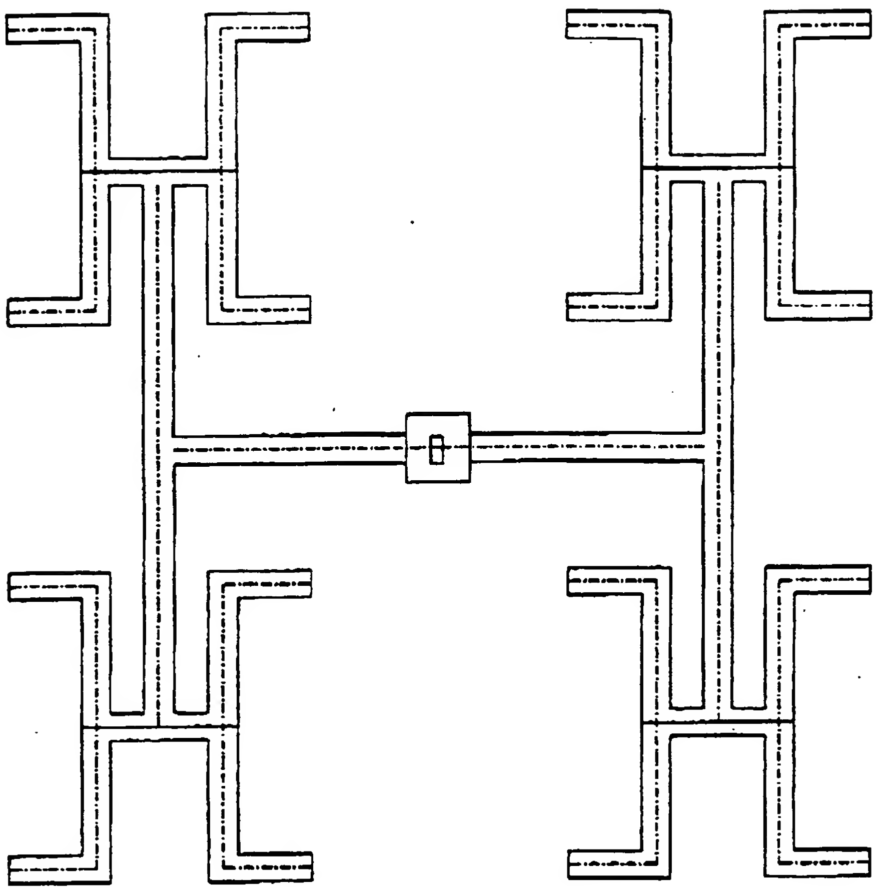


FIG. 10

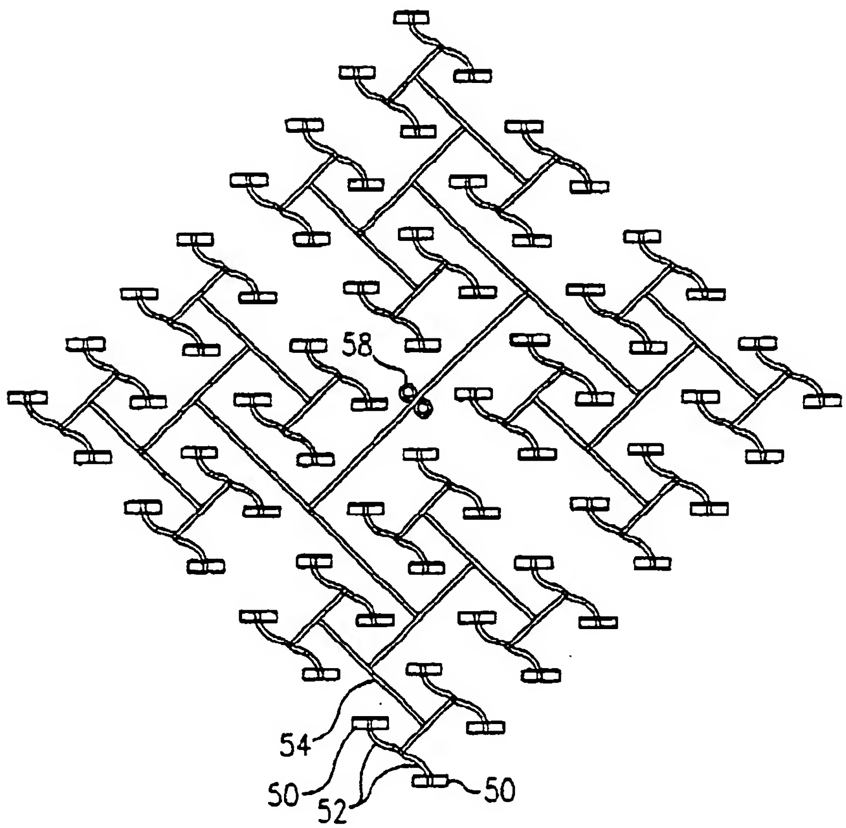


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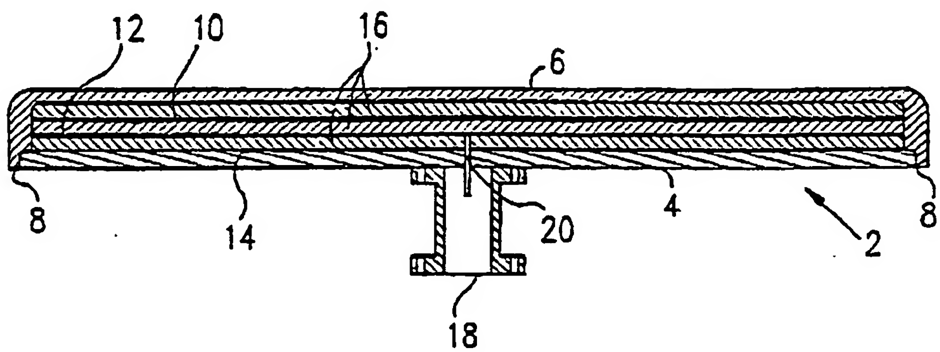
FIG. 1



EP 0 910 134 A3

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Application Number
EP 98 30 8385

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

- [ ] Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid, namely claim(s):

- [ ] No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

- [ ] All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

- [ ] As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

- [ ] Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

- [x] None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

  1-10,12-21,24-29

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 98 30 8385

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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30-10-2000

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